Taxonomy of the *Litoria aurea* complex: a re-evaluation of the Southern Tableland populations of the Australian Capital Territory and New South Wales

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ABSTRACT

The Southern Tablelands populations of the *Litoria aurea* complex were studied to determine the status of each taxon. Examination of colour-pattern, morphology and advertisement calls was used to determine the extent of variation present in each taxon in the area and to determine if any additional species were present. Three taxa were found to occur on the Southern Tablelands: *Litoria aurea, Litoria raniformis* and *Litoria castanea. Litoria castanea* is restricted to the New England region of New South Wales and the Southern Tablelands of the Australian Capital Territory and New South Wales. All three taxa from the Southern Tablelands are distinguishable by differences in both morphology and advertisement call. The nomenclature of the population variably known as *L castanea* or *L flavipunctata* was determined and the former name is recommended. A key to the taxa within the *L aurea* complex in south eastern Australia has been constructed. Further research on the distribution and taxonomy of the group is recommended to determine if populations of *L castanea* on the Southern Tablelands represent the same species as the disjunct populations on the Northern Tablelands.

INTRODUCTION

The *Litoria aurea* complex (*sensu* Courtice and Grigg 1975), or bell frogs, consists of six described species; two from Western Australia, *L. cyclorhyncha* and *L. moorei*; one from northern Australia, *L. dahli;* and three from eastern Australia, *L. aurea, L. flavipunctata* and *L. raniformis* (Courtice and Grigg 1975). Previously only two species were thought to occur in the Southern Tablelands, *L. aurea* and *L. raniformis* (Courtice 1972; Cogger 1992; Tyler 1992). However, subsequent to the description of *L. flavipunctata* (Courtice and Grigg 1975) some believed that instead of *L. raniformis*, a *flavipunctata*-like population existed in the Australian Capital Territory (Humphries 1979; Watson and Littlejohn 1985; J. Wombey, pers. comm.).

Litoria aurea was originally described as *Rana aurea* from Bathurst, New South Wales, (Lesson 1831), and was subsequently moved to the genus *Hyla* (Gunther 1858). All Australo-Papuan members of the genus *Hyla* were separated on the basis of vocal sac musculature (Tyler 1971) and placed in the genus *Litoria* Tschudi (1839). *L. aurea* is essentially a coastal species, occurring from the north-coast of New South Wales to the East Gippsland region of Victoria (Fig. 1); however, it does appear to have a significant inland population on the Southern Tablelands (Courtice and Grigg 1975; Brook 1983). On the Southern Tablelands, the species does not appear to occur above about 800 m (Osborne *et al.* 1996); similarly in Victoria, the species does not occur above about 500 m in the Cann River region (Gillespie 1996).

Litoria raniformis was originally described as *Chirodryas raniformis*, type locality unknown (Keferstein 1867). Although the species was subsequently synonymized with *Hyla aurea* (Keferstein 1868), the name *raniformis* was later resurrected for the inland form of *H. aurea* (Parker 1938), where it was given species status in 1975 (Courtice and Grigg 1975). *L. raniformis* has a broad distribution, occurring from south-eastern South Australia, throughout much of Victoria and southern New South Wales west of the Great Dividing Range (Courtice 1972; Brook 1983). *L. raniformis* occurs at high altitudes with the highest museum record (Museum of Victoria 44799) being from near Nimitabel (1150 metres), New South Wales. *L. aurea* and *L. raniformis* can be distinguished by the presence of a vertebral stripe, and warts on the dorsum, both of which are absent in *L. aurea*, and by the presence of enlarged distal pads on the toes of *L. aurea*, which are absent in *L. raniformis* (Courtice and Grigg 1975). Two zones of contact between these species have been recognized: one in the Canberra region of the Southern Tablelands, and the other in the East Gippsland region of Victoria (Courtice and Grigg 1975; Watson and Littlejohn 1975; W. Sherwin, pers. comm.).

The third species found in southeastern Australia is *L. flavipunctata* (Courtice and Grigg 1975) from the New England Tablelands in northern New South Wales (Fig. 1). This species can be distinguished from *L. raniformis*, which it closely resembles, by the presence of large yellow spots

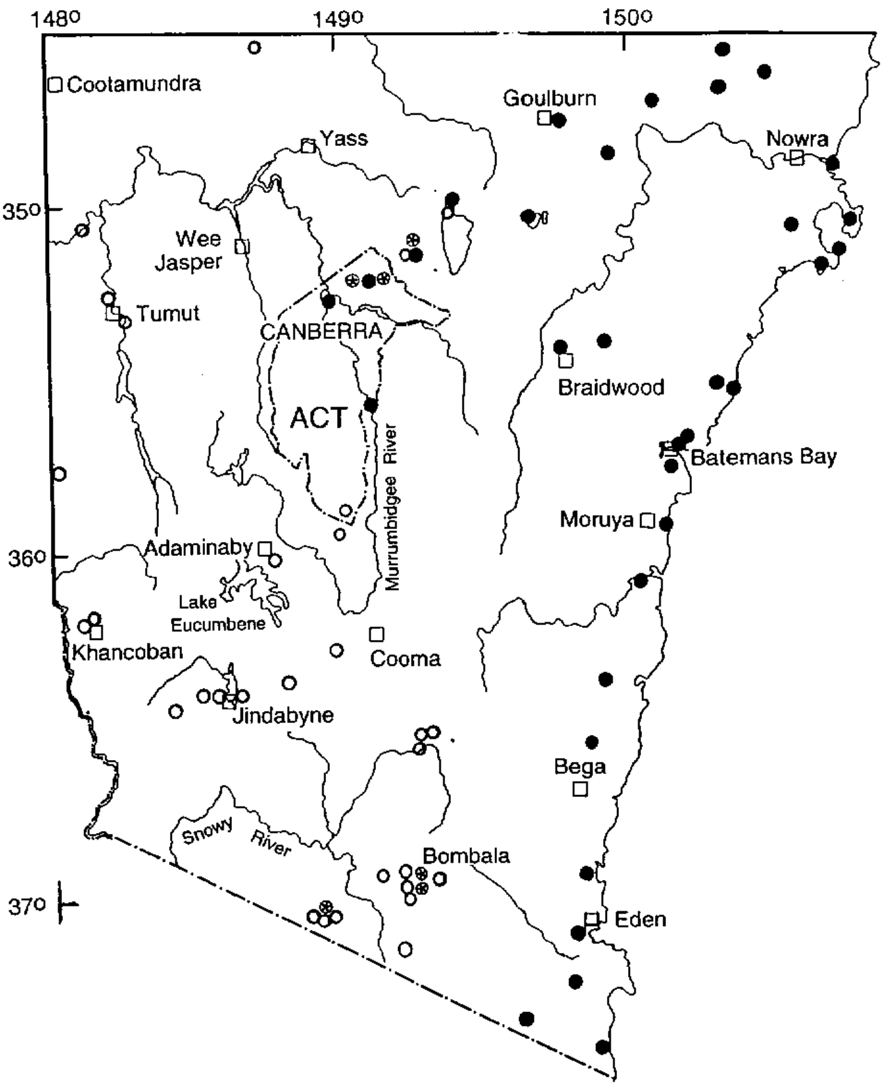


Fig. 1. Distribution of *Litoria aurea* ●, *L. flavipunctata* ⊕ and *L. raniformis* ○ on the Southern Tablelands. All records based on examination of museum specimens.

in the groin, and by yellow and black marbling on the lateral-ventral surface and on the ventral surface of the thighs (Courtice and Grigg 1975).

Recent concern about the possible disappearance of the *L. aurea* complex from the Southern Tablelands (Osborne 1990; Osborne *et al.* 1996), and disagreement about the members of the complex present in this area, encouraged us to reconsider the taxonomy of the populations. In this paper, we present findings based on analysis of morphology, colour patterns and advertisement calls, which indicate that all three species occurred in the Southern Tablelands. We also include a field key to the *L. aurea* complex for Eastern Australia.

METHODS

Morphology

Specimens from the Australian Museum (AM), Museum of Victoria (MV), Australian National Wildlife Collection (CSIRO) (ANWC) and the University of Canberra (UC) were examined to obtain morphological and distributional data for each taxon. All available specimens from the Southern Tablelands were examined, along with a selection of specimens from other areas. Distributional information was derived from examination of locality records accompanying museum specimens, and from a number of photographs with accompanying locality information.

Morphology and colour pattern were examined and character states assigned for 17 characters (Table 1) in the complex. Unordered states were used with a hypothetical ancestor and analysed using PAUP 3.1 (Swofford and Begle 1993). Phylogenetic analysis using species-level states was undertaken for 248 specimens; multi-state characters were maintained and considered as a polymorphism.

Table 1. Seventeen character states used in PAUP analysis.

No	Character	State = 0	State = 1	State = 2
1	Vertebral stripe	absent	present	n/a
2	Toe pads	>toe width	≤toe width	n/a
3	Webbing	½ to ¾ webbing	slightly < fully webbed	fully webbed
4	Groin colour	blue	blue with occasional small white spots	blue with large yellow spots
5	Dorsum	smooth	warty	n/a
6	Dorsolateral fold	yellow	gold	n/a
7	Grannular skin	grannular on throat belly and thighs	grannular on belly and thighs	grannular on lower belly or smooth
8	Ventral coloration	cream to white	fine reticulated pattern on ventral surface of thighs and belly, may include throat	n/a
9	Dorsal leg colour	brown or gold blotching on upper surface of legs	legs green	n/a
10	Ventral leg colour	mottled or uniform in colour	large yellow/brown blotching	n/a
11	Dorsolateral stripe	continuous	broken	n/a
12	Antero-lateral aspect of groin	uniform or small white spots	large white spots present	n/a
13	Subocular stripe	stripe from base of eye to fore leg	absent	n/a
14	Yellow spots upper surface of foot	absent	present	n/a
15	Dorsal coloration	large blotch-like pattern (metalic or brown)	absent	n/a
16	Post-nari stripe	present (black stripe nasal to eye)	absent	n/a
17	Latero-ventral colour	cream to white	pattern of large yellow and black/brown blotches present	n/a

A subset of adult frogs consisting of 22 *L. aurea,* 26 *L. raniformis* 16 *L. flavipunctata* (Northern Tablelands form), and seven *L. flavipunctata* (Southern Tablelands form) were selected, and 15 morphological measurements (Table 2) were taken using vernier calipers accurate to 0.1 mm. Each measurement was taken on the right side where possible, and was measured by the same person for each frog. To standardize effects caused by variation in specimen size, 17 additional ratio measurements were calculated (Table 2). All 32 variables were entered into a stepwise discriminant analysis using SAS®. The variables that showed best discrimination between; (a) all four taxa; (b) *L. aurea* and all other taxa grouped; (c) *L. raniformis, L. flavipunctata* (Northern Tablelands form) and *L. flavipunctata* (Southern Tablelands form), and; (d) *L. flavipunctata* (Northern Tablelands form) and *L. flavipunctata* (Southern Tablelands form) were subsequently used in a canonical discriminant function analysis (Manly 1991) using SAS®. The canonical discriminant functions were verified by using cross-validation (SAS/STAT™ 1988, Diekhoff 1992).

Advertisement Calls

As yet there are no objective and physical descriptions of the advertisement calls of the *L. aurea* complex of southeastern Australia (*sensu* Wells 1977; Littlejohn 1977). Tape

Table 2. Measurements taken and ratios calculated for use in stepwise discriminant anlysis.

Abbreviated variable name	Variable
SVL	snout-vent length
HL	head length
HW	head width
TIB	tibia length
VK	vent-knee length
FOOT	foot length
RAD	radius
HD	head depth
EW	eye width
TYMP	tympanum diameter
INARIS	inter naris distance
ENARIS	eye-naris distance
EL	eye length
NARIS	naris-snout length
LEG	foot+vk+tibia
RATIO 1	HL/HW
RATIO 2	SVL/HL
RATIO 3	VK/TIBIA
RATIO 4	HL/TIBIA
RATIO 5	VK/FOOT
RATIO 6	FOOT/RAD
RATIO 7	EW/INARIS
RATIO 8	ENARIS/INARIS
RATIO 9	INARIS/NARIS
RATIO 10	FOOT/TIBIA
RATIO 11	HW/INARIS
RATIO 12	SVL/VK
RATIO 13	SVL/TIBIA
RATIO 14	HW/TYMP
RATIO 15	ENARIS/TYMP
RATIO 16	SVL/LEG
RATIO 17	ENARIS/HL

recordings of identified calls of *L. aurea* and *L. raniformis* are presented on a tape cassette (Littlejohn and Smith 1987). Given the complex and variable nature of the advertisement calls (M. Littlejohn, unpubl. obs.), the analysis was confined to the interpretation of waveforms. The following descriptions are based on the calls of 12 individuals of *L. flavipunctata*, and of six individuals of *L. aurea*, obtained at Oakdale, near Canberra, during October 1975 and October 1976. In addition, calls of numerous other individuals of these species were also heard at Oakdale. Calls of many other individuals of *L. aurea* and of *L. raniformis* have also been heard at other localities across the geographic range of each taxon (M. Littlejohn, unpubl. obs.), and thus the calls described here are believed to be representative of each taxon. At Oakdale, and in the adjacent Australian Capital Territory, the two types of call (*L. aurea* and *L. flavipunctata*) appeared to be distinctive, based on subjective auditory assessment, with no suggestions of intergradation or intermediates that could reflect hybridization.

Recordings

Calls were recorded at breeding sites with an open-reel tape recorder (Nagra IIIBH; tape speed 19 cm s^{-1}) and either a Beyer M-88 cardioid dynamic, or an Electro-Voice EV-644 shot-gun microphone. The frogs were calling while floating in open water. The surface water temperature at the calling site was measured with a quick-reading liquid-glass expansion thermometer (Wesco) at the conclusion of each recording sequence for an individual.

The recordings of one individual of *L. flavipunctata* (reference reel 307, Cut #14) and of one of *L. aurea* (reference reel 308, Cut #15) were obtained at water temperatures of 16.2°C and 17.5°C, respectively, at "Oakdale", approximately 5 km north-east of Sutton, New South Wales (35°08'S, 149°17'E), on 6 October 1975. The recording of the call of *L. raniformis* (reference Reel 279, cut #10) was obtained from a flooded roadside area, at a water temperature of 15.5°C, 12.0 km south-west of Moyston, Victoria (37°21'S, 142°40'E), on 10 October 1973. One transcript of *L. flavipunctata* from the tape cassette, "Frog Calls of S.E. Australia" (Grigg and Barker 1977) was also studied, namely selection 43 (our reference GB 43) from 12.8 km west of Guyra, New South Wales (no other data provided).

Analysis

Open-reel recordings were replayed on a Sony TC-510-2 tape recorder, with the line output directed to the line input of a 16-bit audio-card (Sound Blaster 16, Creative Technology Ltd) installed in a 486DX/33 desk-top micro-computer. Analogue signals were converted into digital form at a rate of 22 050 samples s^{-1}, and files saved in the "wave" format (.wav) for reference and acoustic analysis. The first three or four distinct acoustic signals ("notes") in one clear calling sequence of one individual were analysed. Waveforms were prepared with the software package WaveStudio (Creative Technology Ltd). Spectral information was obtained by analysing the same files with the software package, Spectra Plus Professional, Version 3.0, (Pioneer Hill Software). For the preparation of the figures of single notes, separate edited files of durations of 2 s were produced from the original digitized signals, and hard copies obtained by laser-printing the screen images. To reduce the high background levels caused by calls of other species, all the files were digitally low-pass filtered (Spectra Plus, sharp roll-off at 1500 Hz) before preparation of the Figures.

Peak frequencies in each note were obtained from the indicated value given during the analysis with Spectra Plus in the spectrum mode (FFT = 512 samples; resolution = 43 Hz). Values of a clear secondary peak, and the level (in dB) below the peak frequency, were also noted. Spectral bandwidths at –20 dB below the peak frequency on the spectral display of the last note in the analysed sequence were estimated.

The transcript from the tape cassette of Grigg and Barker (1977) was replayed on a Nakamichi Dragon cassette recorder (tape speed 4.76 cm s^{-1}), and digitized and analysed as outlined above.

Specimens Examined

***Litoria aurea*: C/A** 150, 155, 305, 313, 314–29, 340–43, 414–22, 537–8; **UC** 0042–43, 0045–46, 0158–60; **MV** D18907–08, D19617, D19620–21, D19700, D19712–14, D19716–19, D62457; **AM** R45739–56, R45766–71, R71689–99, R74552–55; **ANWC** A0300, A0322–23, A0389, A0390, A0450, A0666. ***Litoria flavipunctata*: C/A** 536, **UC** 0047, 0155; **MV** D19286, D19494–96, D19608–09, D62329–32, **AM** R32183–91, R32545–54, R34814–17, R51293–96, R51700–02, R74608–10; R93881, **ANWC** A0218, A0649, A1280, A1495: ***Litoria raniformis*: C/A** 153–54, 411, 423, 562; **UC** 0044, 0156–57; **MV** D6686–88, D6693–99, D7128–30, D19051–54, D19062–63, D19110–16, D19263–65, D19280, D19480–86, D19531, D19593–603, D19649–54, D19660–61, D19668, D19729–32, D44799–800, D44898–99, D62359–61, D62363, D62455–57, **AM** R5233, R25851–55, R74606–07, R74891, R90789, R93243, R98146–50, R118488, **ANWC** A1498, A1501, A1502.

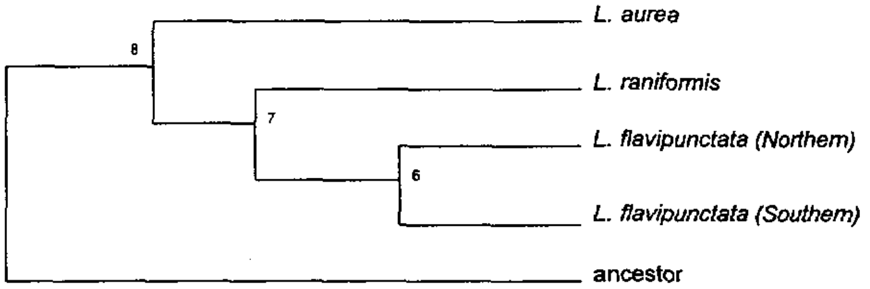
RESULTS

Morphology and Colour Pattern

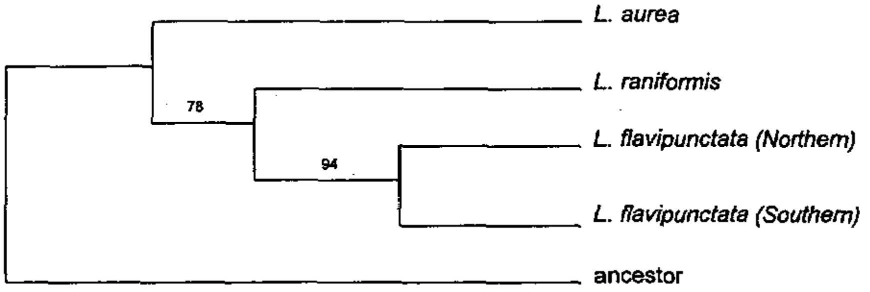
Character-state analysis (Table 3) demonstrated a clear dichotomy between *L. aurea* and the other two species. This is most clearly represented by the presence of distal toe pads in *L. aurea* and their absence in *L. raniformis* and *L. flavipunctata*. Furthermore, there was a clear dichotomy between *L. raniformis* and *L. flavipunctata*, with

Table 3. Character matrix for each of the four populations analysed. Multistate taxa represented by, for example, (01).

	Character number																
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
L. aurea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(01)	0	0
L. raniformis	1	1	(01)	1	1	1	1	(01)	(01)	0	(01)	(01)	(01)	0	1	(01)	0
L. flavipunctata northern	1	1	2	2	1	1	1	1	0	1	1	1	1	1	1	1	1
L. flavipunctata southern	1	1	2	2	1	1	1	0	0	1	1	1	1	0	1	(01)	0



a) Shortest tree found by Paup. Length=23 , CI=1.000 , RI=1.000 , HI=0.304



b) Bootstrap 50% Majority Rule consensus tree.

Fig. 2. Most parsimonious tree and bootstrap from PAUP analysis.

these two being distinguished by the presence of large yellow spots in the groin of *L. flavipunctata*.

The initial analysis placed most of the specimens into expected groupings: *L. aurea, L. raniformis* and *L. flavipunctata*. PAUP differentiated four populations with *L. aurea* as the sister group to all others (Fig. 2) and *L. raniformis* as the sister group of the northern and southern populations of *L. flavipunctata*. Although there were slight differences between the northern and southern populations, they are not considered to be significantly divergent enough for species status. The last tree (Fig. 2a), length 23, had a consistency index (CI) of 1.000, a retention index (RI) of 1.000 and a homoplasy index (HI) of 0.304. Once a single tree was obtained, this was bootstrapped (Fig. 2b) giving a 50% majority rule consensus tree.

Discriminant Analysis of Morphology

The stepwise discriminant analysis found that the ratio variables 1, 2, 9, 11, 15 and 16 were significant in discriminating between all four taxa (Table 4). Entering these variables into the discriminant function analysis revealed that the *L. aurea* group was quite distinct from the other three taxa on the first canonical variable (Fig. 3) which explained 84.4% of the variation (Table 4). Neither of the other taxa could be distinguished from each other on either the first or second canonical variable (Fig. 3). The high error rate when trying to distinguish between all taxa at once (Table 4) was caused by *L. aurea* being more different from the other taxa than the other taxa were from themselves (Fig. 3). This outcome is consistent with PAUP finding of a clear dichotomy between *L. aurea* and all other species (Fig. 2).

Table 4. Results from stepwise discriminant analysis and cross validation of canonical discriminant function analysis.

Taxa discriminated between	Significant variables	Variation explained by first discriminant function	Per cent of individuals incorrectly classified after cross-validation				
			L. aurea (*n* = 22)	*L. raniformis* (*n* = 26)	*L. flavipunctata* (northern) (*n* = 16)	*L. flavipunctata* (Tablelands) (*n* = 7)	Total errors
L. aurea, *L. raniformis*, *L. flavipunctata* (northern), *L. flavipunctata* (Tablelands)	ratio 1, ratio 2, ratio 9, ratio 11, ratio 15, ratio 16	84%	0	38	44	28	28
L. aurea all others grouped	ratio 1, ratio 2, ratio 3, ratio 9	na	0	na	na	na	2
L. raniformis, *L. flavipunctata* (northern), *L. flavipunctata* (Tablelands)	ratio 9, ratio 11, ratio 15, ratio 16	63%	na	31	37	29	32
L. flavipunctata (northern), *L. flavipunctata* (Tablelands)	ratio 11, ratio 15	na	na	na	6	14	10

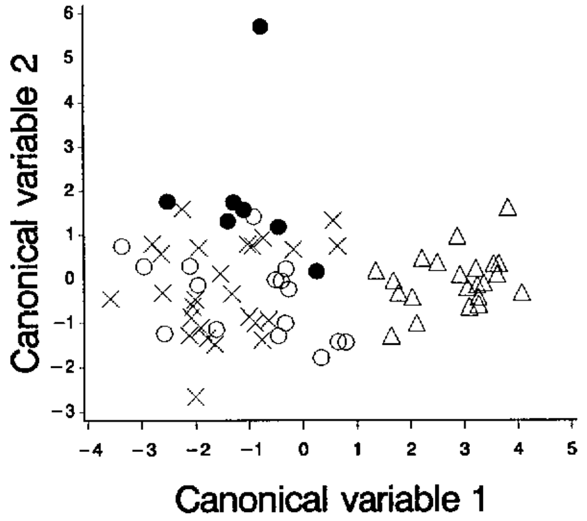


Fig. 3. Ordination on first two canonical variables of specimens from the *Litoria aurea* complex used in canonical discriminant function analysis. Triangle = *L. aurea*, cross = *L. raniformis*, open circle = *L. flavipunctata* (Northern Tablelands form), solid circle = *L. flavipunctata* (Southern Tablelands form).

Subsequent analysis suggested that ratio variables 1, 2, 3 and 9 (three size and one nasal measurement ratios) could discriminate *L. aurea* from all other species with a minimal error rate (Table 4). Ratio variables 9, 11, 15 and 16 were significant when discriminating between *L. raniformis* and the two forms of *L. flavipunctata* (Table 4); however, the cross validation results showed this discrimination to be poor (Table 4). Analysis of the measurements of only the two forms of *L. flavipunctata* found that only ratio variables 11 and 15 (both calculated from head morphology) were needed for significant discrimination (Table 4), with only one individual from each population being misclassified, giving an error rate of 10% (Table 4). The distribution of these frogs on the canonical variate does show some overlap, however (Fig. 4).

Advertisement Calls

The advertisement call of *L. aurea* (Fig. 5a) is clearly diphasic (*sensu* Littlejohn and Harrison 1985), with one or two long introductory notes ("growls") having smooth envelopes of gradually increasing amplitude and abrupt terminations, and fully pulse modulated at 104 (at start) to

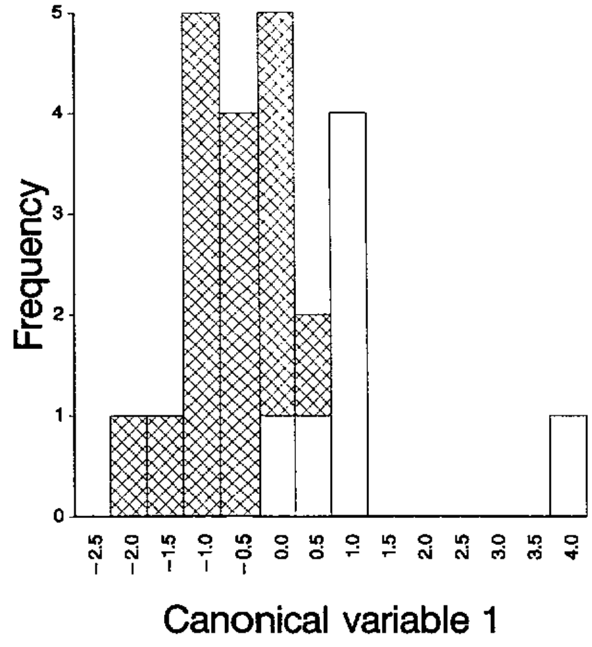


Fig. 4. Distributions of *Litoria flavipunctata* (Northern Tablelands form) and *Litoria flavipunctata* (Southern Tablelands form) along canonical variate calculated from ratio variables 11 and 15. Cross hatching = Northern Tablelands form. Open bars = Southern Tablelands form.

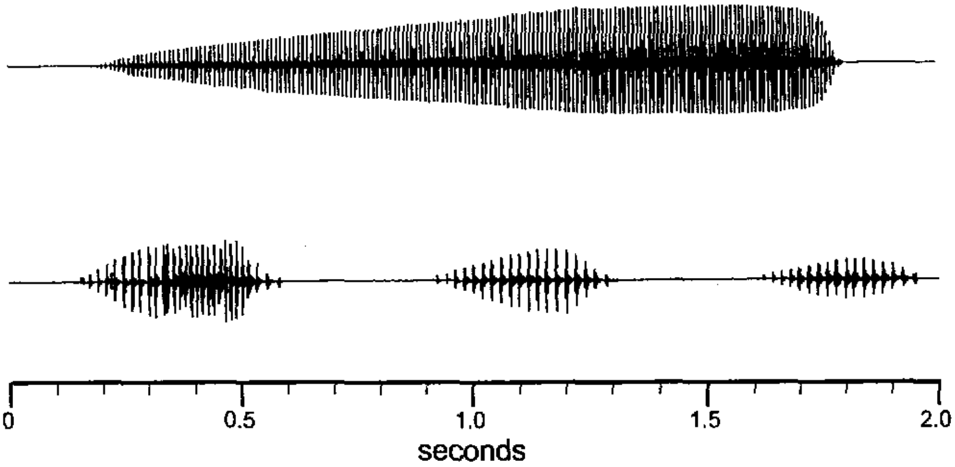


Fig. 5a. Waveforms of a long introductory note (upper trace) and three shorter following notes (lower trace) in the advertisement call of *Litoria aurea* (reference Reel 308, #15) from Oakdale, *ca* 5 km north-east of Sutton, New South Wales, recorded at a water temperature of 17.5°C.

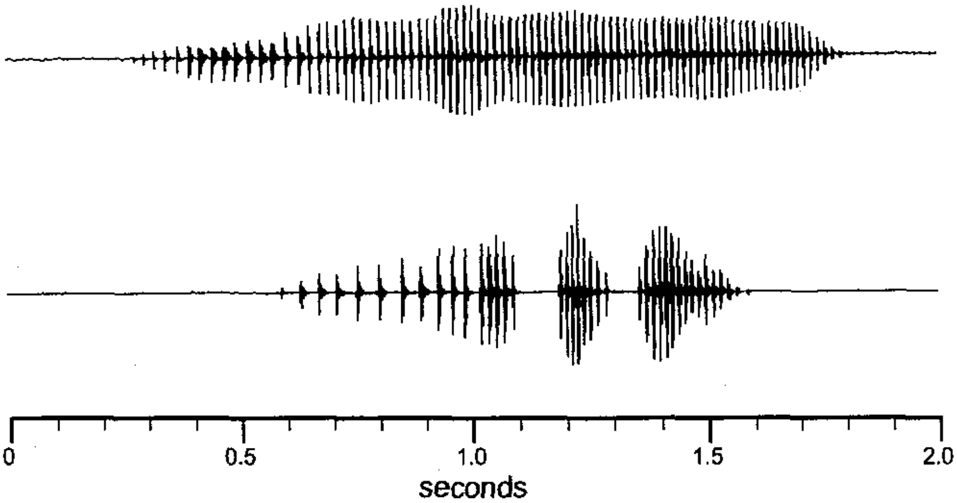


Fig. 5b. Waveforms of an introductory note (upper trace) and one following note (lower trace) in the advertisement call of *Litoria raniformis* (reference Reel 279, #10) from 12 km south-west of Moyston, Victoria, recorded at a water temperature of 15.5°C.

114 (at end) pulses s^{-1}. One to several shorter pulse trains ("grunts") usually then follow. For the last note in the file, the main peak frequency is 1 205 Hz; and there is a secondary peak at 432 Hz (6 dB below the level of the peak frequency), and a band of frequencies (at –20 dB) between 322 and 1 811 Hz. The grunts are amplitude modulated to give a clear but irregular pulsatile envelope.

L. raniformis has a clearly diphasic advertisement call (Figure 5b), with a long introductory note ("growl") of smooth envelope of gradual attack and decay, which is fully pulse modulated at rates of 42 (at start) to 68 (at end) pulses s^{-1}. The following short grunts are also of variable structure, and may be fully amplitude modulated in an irregular way. For the last note, the peak frequency is 1 119 Hz, with a secondary peak at 391 Hz (at –10 dB). The bandwidth (at –20 dB) ranges from 280 to 1 750 Hz.

The call of *L. flavipunctata* (Southern Population, Fig. 5c) is variable but basically monophasic, and a sequence of several short clearly-pulsed notes ("grunts"), which are sometimes lengthened into short growls, can be produced during a calling sequence. Although often fully amplitude modulated to give distinct pulses, there is not a regular pattern. No long introductory growls, characteristic of *L. aurea* and *L. raniformis*, were noted. The value for the main peak frequency in the last note is: 1 033 Hz, with a secondary peak at 400 Hz (at –7 dB). The bandwidth (at –20 dB) is between 315 and 1 503 Hz.

Calls of *L. flavipunctata* (Northern Population, Fig. 5d) from the selection on the tape cassette of Barker and Grigg (referred to as GB43) consist of short clearly pulsatile notes, with no indications of diphasy. In this regard, they are most similar to the call of *L. flavipunctata* from

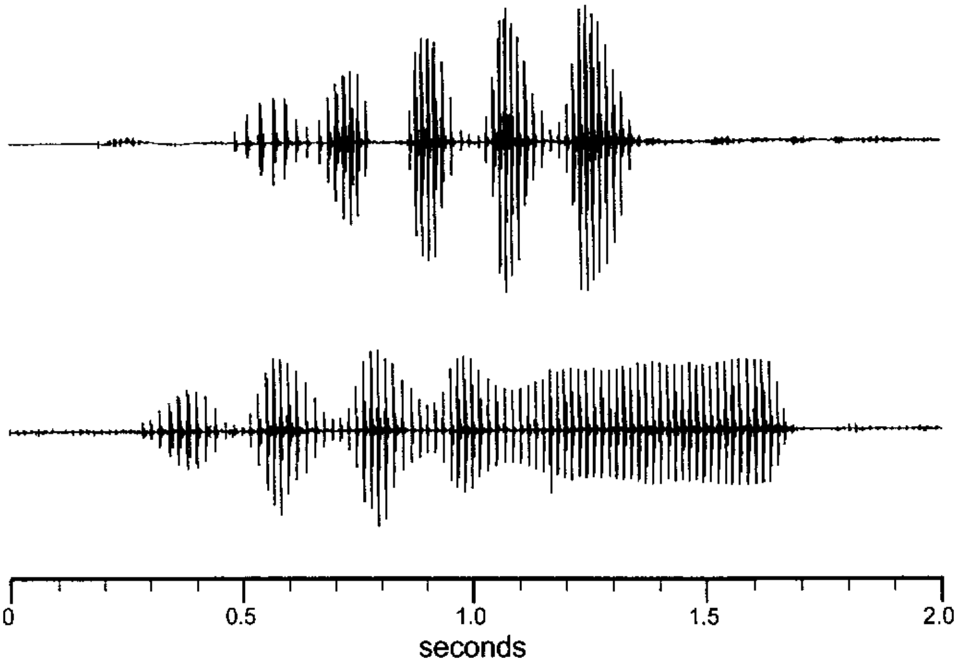


Fig. 5c. Waveforms of a pulsed note (upper trace) and a transitional "growling" note (lower trace) in the advertisement call of *Litoria flavipunctata* (reference Reel 307, #14) from Oakdale, *ca* 5 km north-east of Sutton, New South Wales, recorded at a water temperature of 16.2°C.

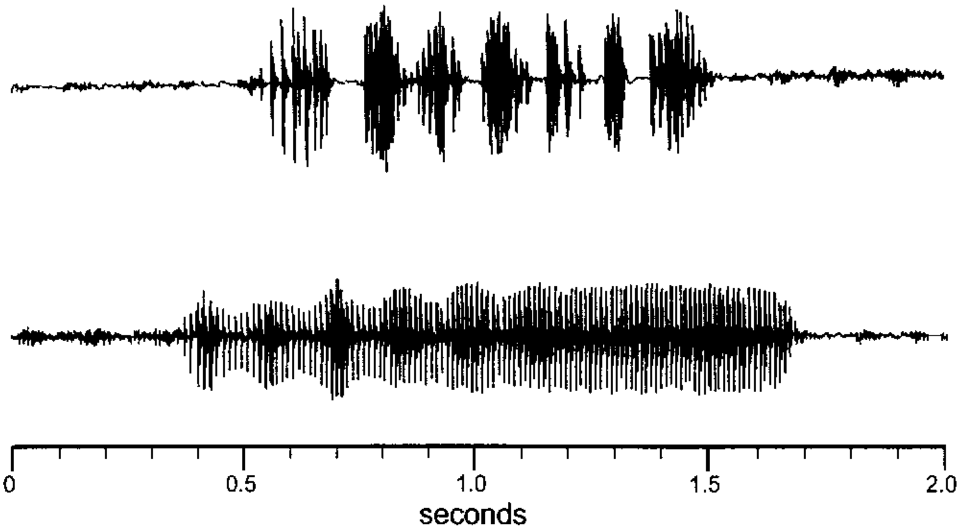


Fig. 5d. Waveforms of two notes in the advertisement call of *Litoria flavipunctata* (reference GB 43) from 12.8 km west of Guyra, New South Wales (no temperatures are available).

Oakdale, near Canberra. For GB43, the equivalent values are 387 and 821 Hz (at less than 1 dB lower), and a bandwidth of 178 to 1 150 Hz. However, because the cassette recording is a product of several generations of copying, these values may be slightly inaccurate.

DISCUSSION

This study supports the finding of Courtice and Grigg (1975) that *L. aurea* (plate 1e) and *L. raniformis* (plate 1d) occurred in the Southern Tablelands. However, our findings are also in agreement with the suggestions of Humphries (1979) and Watson and Littlejohn (1985) that *L. flavipunctata* (plates 1b, 1c) also occurred on the Southern Tablelands. The three species occur in sympatry (Fig. 1), although only *L. raniformis* and *L. flavipunctata* appear to have occurred at high altitude.

The northern (New England) and southern populations of *L. flavipunctata* show some divergence in colour pattern and head morphology. Although the black and yellow marbling on the ventral surface of the thigh is present

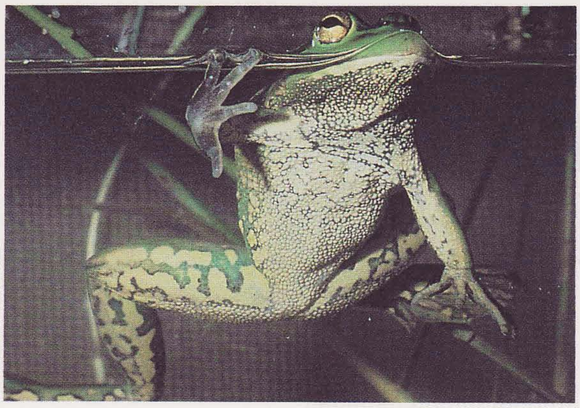


Plate 1a. Ventral surface of *Litoria castanea* showing characteristic markings. New England Tablelands 1965. Photo: D. Clyne.

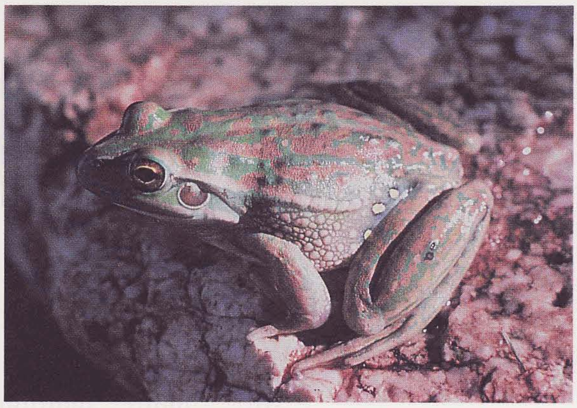


Plate 1b. Litoria castanea, Canberra, 1976. Photo: J. Wombey.

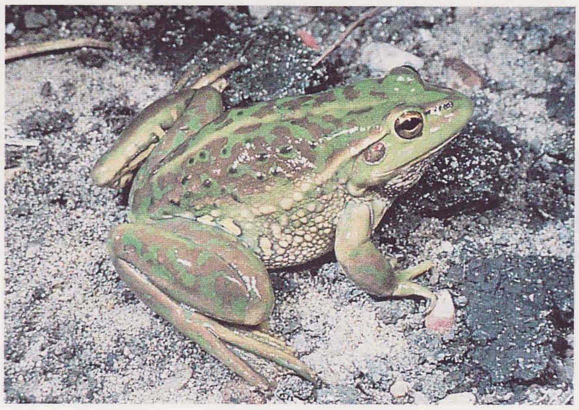


Plate 1c. Litoria castanea, Guyra, 1972. Photo: G. Grigg.

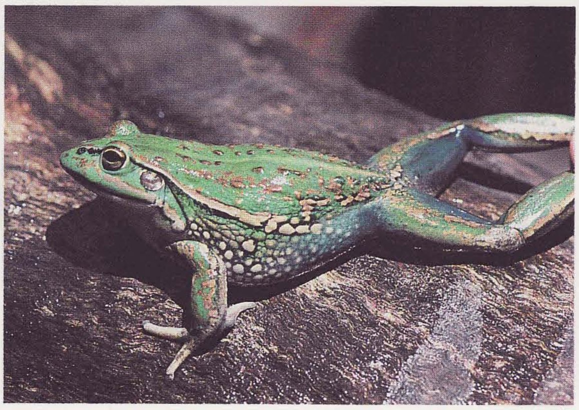


Plate 1d. Litoria raniformis, Shannon's Flat, near Canberra, 1979. Photo: P. Ormay.

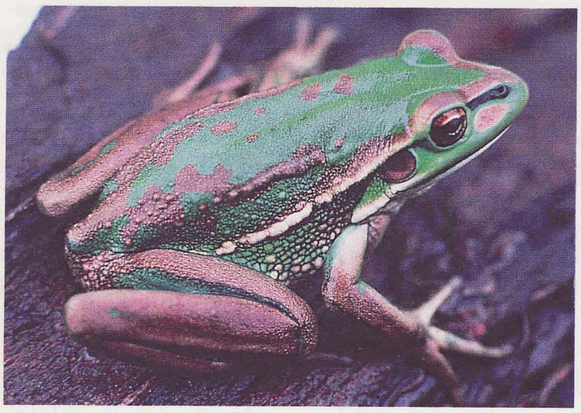


Plate 1e. Litoria aurea, Gungahlin, Canberra, 1976. Photo: J. Wombey.

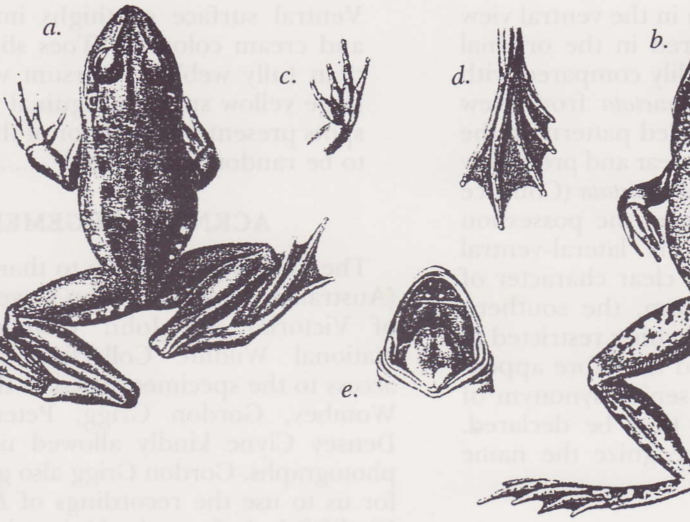


Fig. 6. Line drawing of the holotype of *Hyla* (=*Litoria*) *castanea* from the original description by Steindachner (1867), (a) dorsal view; (b) ventral view; (c) fore foot; (d) hind foot; (e) mouth.

in both populations, the extent and definition of these markings differs slightly. In the Northern Tablelands form, the marbling extends to the latero-ventral surface; whilst in the southern form, it stops at the inguinal area. Secondly, the intensity or definition of this patterning is sharper and clearer in the Northern Tablelands form. Another distinguishing feature is the general lack of white or yellow spots on the feet the southern population. The southern form also tends to be darker in general colour, more of a rich emerald green when compared with a lime green in the north. Given these differences, and the successful discrimination based on morphological characters between the small samples, it is possible that each form represents a unique population. However, in the absence of further information and no detectable difference in the advertisement calls, the slight differences reported here are considered to be consistent with their disjunct allopatry and are clearly not indicative of sufficient taxonomic divergence to warrant formal recognition at this stage.

The Nomenclatural Status of L. flavipunctata

The nomenclature for *L. aurea* and *L. raniformis* is not problematic; however, this is not the case for *L. flavipunctata*. Although it was described as a new taxon in 1975, just eight years later it was suggested that the older name *L. castanea* was synonomous (Cogger *et al.* 1983). The specimen described as *Hyla castanea* (Steindachner 1867) was obtained on the Novara expedition, and it has been suggested by some that it is not possible for this animal to have been obtained from the now known range of *L. flavipunctata* (M. Tyler, pers. comm.). The expedition was in Australia, specifically at Port Jackson, from 5 November 1858 to 7 December 1858 (Gans 1955). In this period, they visited and collected in areas such as Sydney, Camden Park, Campbelltown, Appin, Bargo, Wollongong, Kogarah Bay and Long Bay (Gans 1955). However, the type locality is listed as unknown (Steindachner 1867), and it is possible that this specimen was not collected by the expedition but may have been obtained later. As this has been a contentious issue in the past, and in an effort to finally resolve it, we consider it useful to publish a complete translation of the original description of *Hyla castanea*. Translation of the original description (in German) from Steindachner is as follows:

> *Hyla castanea*
>
> Body slender, slim; head tapering; snout long; without prominent edge; Tympanum smaller than eye; distal pads small, round; fingers free; toes completely connected with wide web; thumb of male very strong enlarged at the base, compared to other fingers; wrist weakly developed; edge of the first carpal longish, small; a pair of skin folds on the tarsal edge; an unclear skin fold over the tympanum; two short converging palatine teeth between the interior nostrils; mouth of oesophagus wide; tongue large, long round, back edge slightly indented dorsum smooth, chestnut brown, velvet like, with not very clear, darker, round spots; side of body and the extremities black with irregular large white spots and marbled with black; abdomen and part of ventral surface of back thigh warty; male with simple throat sack; male throat black marbled, warty.
>
> A large specimen (male) ; site of discovery unknown.

L. castanea has been previously synonymized with *L. aurea* (Courtice and Grigg 1975), and prior to this it was considered to be a synonym of *L. aurea raniformis* (=*L. raniformis*) (Moore 1961). The specimen described as *Hyla castanea* (Steindachner 1867) possesses all of the characters which distinguish *L. flavipunctata*, including those which distinguish it from the southern form. These can best be seen in the ventral view of the holotype as it appeared in the original description (Fig. 6), and readily compared with a ventral view of a *L. flavipunctata* from New England (Plate 1a). The marbled pattern on the ventral surface of the legs is a clear and previously described character for *L. flavipunctata* (Courtice and Grigg 1975). Furthermore, the possession of a marbled pattern on the lateral-ventral surface of the abdomen is a clear character of the Northern Tablelands form, the southern form having this ventral patterning restricted to the legs (this study). It would therefore appear that the name *castanea* is a senior synonym of *flavipunctata*, and it should thus be declared. Hence, in this paper we recognize the name *Litoria castanea*.

Diagnosis of Southern Tableland Populations

L. castanea can be recognized by the fully webbed toes and the presence of black and yellow marbling on the ventral surface of the legs. Large yellow, black-ringed spots are present in the inguinal area, and there is a series of yellow spots on the posterior edge of the thigh. A vertebral stripe is usually present, as are warts on the dorsum.

L. aurea can be recognized by its half to three quarter-webbing, and by the lack of a vertebral stripe and warts dorsally. There are no spots present in the inguinal area, nor on the posterior edge of the thigh. There are large distal pads present on the toes.

L. raniformis can be recognized by the lack of black and yellow marbling on the hind legs, and by the lack of black-ringed yellow spots in the inguinal region. If spots are present on the posterior thighs of a specimen of *L. raniformis* then they tend to be white, rather than yellow and concentrated around the vent rather than a series of spots along the thigh. The dorsum is warty and a vertebral stripe is usually present. The feet of *L. raniformis* tend to be slightly less-webbed than those of *L. castanea* (Courtice and Grigg 1975).

Key to the Litoria aurea *Complex in South-eastern Australia*

1. Expanded toe discs absent. 2

   Expanded toe discs present. Toes half to three-quarter webbed. Dorsum smooth. Spots absent from inguinal region, vent and posterior edge of thigh .... *L. aurea*

2. Black and yellow marbled pattern present on ventral surface of legs. Toes fully webbed. Dorsum warty. Large black-ringed yellow spots in inguinal region; series of yellow spots on hind edge of thigh .... *L. castanea*

   Ventral surface of thighs immaculate and cream coloured. Toes slightly less than fully webbed. Dorsum warty. No large yellow spots in inguinal region; if spots present on posterior of thigh, tend to be randomly arranged .... *L. raniformis*

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